Resource

PUBLISHED BY ASAE – THE SOCIETY FOR ENGINEERING IN AGRICULTURAL, FOOD, AND BIOLOGICAL SYSTEMS

JULY 1999

- *Grain Preservation*
- *Penetrating the Problem*
- *Turning up the Heat*
- *Enzymes Unleashed*
- *1998-99 ASAE Annual Report*

ENGINEERING & TECHNOLOGY FOR A SUSTAINABLE WORLD

Penetrating the Problem

Improved devices dig in to measure soil compaction

Randy L. Raper

Soil compaction has been described by researchers and crop producers as a silent thief.

It reduces yields, limits productivity and root growth, and makes plants more susceptible to drought stress. During heavy rains, runoff and erosion occur.

Sensing and measuring degrees and depths of soil compaction can help producers develop management options. Soil cone penetrometers have been used for years to measure soil compaction and to sense root impeding. Their widespread use resulted in the 1968 adoption of ASAE Standard S313, Soil Cone Penetrometer - to ensure soil data uniformity throughout the world. The standard describes the penetrometer unit shape and size and offers advice on construction and wear assessment.

New ASAE Engineering Practice EP542, titled, "Procedures of Using and Reporting Data Obtained with the Soil Cone Penetrometer," was adopted in February 1999 to help users acquire quality data. EP542 describes penetrometers, soil measurements and statistical treatment of problematic measurements.

Also in February, ASAE Standard S313 was revised. The current version is S313.3.

Manual soil cone penetrometers are inexpensive and provide quick soil compaction assessments. The units are commonly composed of a dial gauge for pressure measurement and shaft markings for depth measurement. They are available from companies such as Dickey-john Corp. of Auburn, Illinois; ELE International Inc. of Lake Bluff, Illinois; and Eijkelkamp, based in The Netherlands.

Although handy for quick assessments, these devices are difficult to use for research purposes because two people are required to operate them. One person must push the unit into the soil while another reads and records pressure and depth.

More complicated soil cone penetrometers that automatically record pressures and depth are easier for researchers to use. Three manufacturers that offer these units are Spectrum Technologies Inc. of Plainfield, Illinois; Agridry Rimik of Queensland, Australia; and Eijkelkamp. These penetrometers are more expensive but beneficial when hundreds of measurements are needed to describe soil strength.

Hundreds of data points may be needed to predict soil strength contours across a row.

Several researchers have tried mounting soil cone penetrometers onto vehicles that mechanically, electrically or hydraulically push them into the soil. This method can save time and labor. Improved data quality is provided by the powered devices because insertion rate variations occur less often than when using manually inserted devices.

A concern about acquiring soil cone penetrometer data is variability within fields. Because soil compaction increases with vehicle traffic, differences in soil strength are sometimes measured across a row from a trafficked middle to an untrafficked row middle. "Middle" refers to the area between crop rows. Many replications are typically used to obtain statistical significance between compacted and uncompacted soil conditions. Hundreds of data points may be needed to predict soil strength contours across a row.

Time is another factor in obtaining data. In field experiments, data must be collected quickly to determine soil strength differences before drying or rainfall occur.

During an experiment at the USDA-ARS National Soil Dynamics Laboratory (NSDL) in Auburn, Alabama, it took more than three days to obtain 800 sets of force-depth data with a tractor-mounted soil cone penetrometer. Researchers then decided to design and build a unit with multiple probes that take several readings at one time across a row.

Design criteria for a multiple-probe soil cone penetrometer (MPSCP) were developed in 1994, and development was completed in 1995. The machine fits on a 3-point hitch on the rear of a tractor. A central hydraulic cylinder and the tractor's hydraulic system pushes the shaft vertically into the soil. The tractor's engine speed is calibrated to satisfy Standard S313.3's suggested penetration rate.

A main feature of the MPSCP is its ability to move probes to different locations allowing for row spacings up to 3.96 ft (1.2 m). One of five probes was mounted in each of the following positions across the row:

* in the row middle on the left side,
* midway between the row and the row middle,
* directly in the row,
* midway between the row and

Agricultural engineer Randy L. Raper obtains cone index measurements with the multiple-probe soil cone penetrometer developed at the USDA-ARS National Soil Dynamics Laboratory in Auburn, Alabama.

the other row middle,

l in the other row middle on the tight side.

The second and fourth probes were removed in hard soil conditions to allow increased force on the remaining three probes. In forests or pastures, data from all the probes were averaged for greater precision in determining the cone index.

Individual probes were designed according to Standard S313. A 0.798-in. (20.27-mm) diameter base cone with a 0.625-in. (15.8-mm) diameter shaft was used for the hydraulically powered soil cone penetrometer to meet the standard's stronger drive shaft recommendation. The maximum penetration depth was governed by the length of the probes and stroke length of the cylinder. Typical probe depth lengths were 36 in. (0.91 m) and 30 in (0.76 m) with a frame limitation of slightly more than 39 in. (1 m).

When backed or pulled into plots, the MPSCP was lined up over a row. A row positioning unit adjusted the penetrometer from side to side, sliding the probes 10 in. (0.25 m) in each direction to keep the MPSCP plane perpendicular to the rows.

Load cells with 500-lb (2,224-Newton) individual maximum capacities were used to mount the probes. Each load cell measured cone index values of nearly 7 MegaPascals (1,000 psi) before exceeding capacity, which was sufficient for hardpan soil conditions. Typical values of cone index that stop root growth are near 2 MegaPascals (300 psi).

Penetration depth was measured using a single constant tension spring motor attached to two rigid frame members. When the penetrometer was inserted into soil, frame movement caused the spring motor to contract and record a depth measurement.

An instrumentation system collected data from six sensors on the MPSCP. The data was periodically telemetered back to the NSDL instrumentation vehicle at the edge of the field. The vehicle contained a portable computer, which stored the data for graphing and analysis.

Data were collected based on time increments at an approximate 5-Hz. to 10-Hz. rate. At that frequency, information was obtained at depth increments of roughly 0.1 in. to 0.2 in. (3 mm to 6 mm). The sampling frequency increased when more data was desired.

The MPSCP's versatile design also allowed it to obtain undisturbed cores for bulk density and soil water determination. Aft& removing the penetrometer probes, a tube containing an inner cylinder split into Z-in. (5-cm) rings was mounted on the center bar and inserted into the soil. Removed from the unit, this cylinder was opened and split into multiple increments of soil for bulk density determination.

The MPSCP has been used in field studies to determine cone index and bulk density. One study involved investigating the clay pan soils of central Missouri to determine differences in soil strength between native prairie sod and tillage crop land. A lack of rainfall added to soil strength so only three probes were used. In the prairie, data from the probes were averaged due to lack of traffic and tillage systems.

Another study investigated tillage and weed elimination effects on pecan trees. Trenches created several years earlier with a special tillage and cellulose burial machine were also located using the MPSCP.

The most common MPSCP use has been to determine the effect of tillage and traffic systems on soil compaction. Developing a conservation tillage system for the Tennessee Valley Region in North Alabama included determining soil strength to evaluate the effects of shallow or deep tillage and cover crops.

Combining a global positioning system (GPS) with the MPSCP's ability to determine soil strength across a row allows variability in fragipan and hardpan profiles to be determined throughout fields. Studies in the Southeast collected this type of data, which helps researchers investigate variations in root-impeding layers and to correct it with site-specific tillage.

Data collected with the MPSCP machine have shown variability in soil strength across rows and within fields. This information may lead to site-specific control of soil compaction. R

ASAE member Randy L. Raper is an agricultural engineer with the USDA-ARS, National Soil Dynamics Laboratory, 411 S. Donahue Dr., Auburn, AL 36832, USA; 334-844-4654, fax 334-887-8597, rlraper @eng.auburn.edu, www.eng.auburn .edu/users/rlraper/.